

EXPERIMENTAL ASSESSMENT OF AGGREGATE SURFACING MATERIALS

An MPART Research Proposal

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Submitted to:

Montana Department of Transportation
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2701 Prospect Avenue
Helena, Montana 59620

September 13, 2005

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1 PROBLEM STATEMENT

Highway base courses are typically constructed using crushed and processed aggregate. Roadway designers currently have a number of options for specifying the base course material on Montana Department of Transportation (MDT) highway projects. The engineering characteristics of these various options have not been thoroughly investigated or quantified by MDT; consequently, the designer must rely on experience and habitual practices. This approach often leads to inconsistencies in design and occasionally misunderstandings between designers, contractors, and materials personnel in regards to aggregate specifications.

The two most common options for untreated base course aggregates are described in Section 701.02.4 of the Montana Supplemental Specifications. These materials are known as crushed base courses (CBC). Based on the particle gradation, the two options for untreated base course are: 1) CBC Type A Grade 5, or 2) CBC Type A Grade 6. The maximum allowable particle size for Grade 5 and 6 are 2 in and 1.5 in, respectively.

On some projects, a finer-grained leveling course is substituted for the top 0.15 ft of base course to facilitate leveling and finishing earthwork activities. It is theorized that the smoothness of the finished AC roadway surface is in part a function of the smoothness of the underlying base course surface. Aggregate used for the finer grained leveling course is specified in Section 701.02.6 of the Montana Supplemental Specifications as Crushed Top Surfacing (CTS) Type A. The specifications provide five different particle gradation options for CTS, ranging from a 1-inch-minus to a 3/8-inch-minus maximum particle size. As requested by the Department, this study will focus on the 3/4-inch-minus material specified as Grade 2 CTS.

2 PROJECT OBJECTIVES AND BENEFITS

This study will examine the engineering characteristics of the following three materials:

1. CBC Type A Grade 5 – designated in this proposal as CBC 5A,
2. CBC Type A Grade 6 – designated in this proposal as CBC 6A, and
3. CTS Type A Grade 2 – designated in this proposal as CTS 2A.

As shown in Figure 1, the permissible gradation range of the three materials covers a wide band of particle sizes. Consequently, the performance and characteristics of the base course aggregates could vary widely because the engineering properties of granular cohesionless particles are largely a function of particle size distribution, particle shape, and particle surface texture.

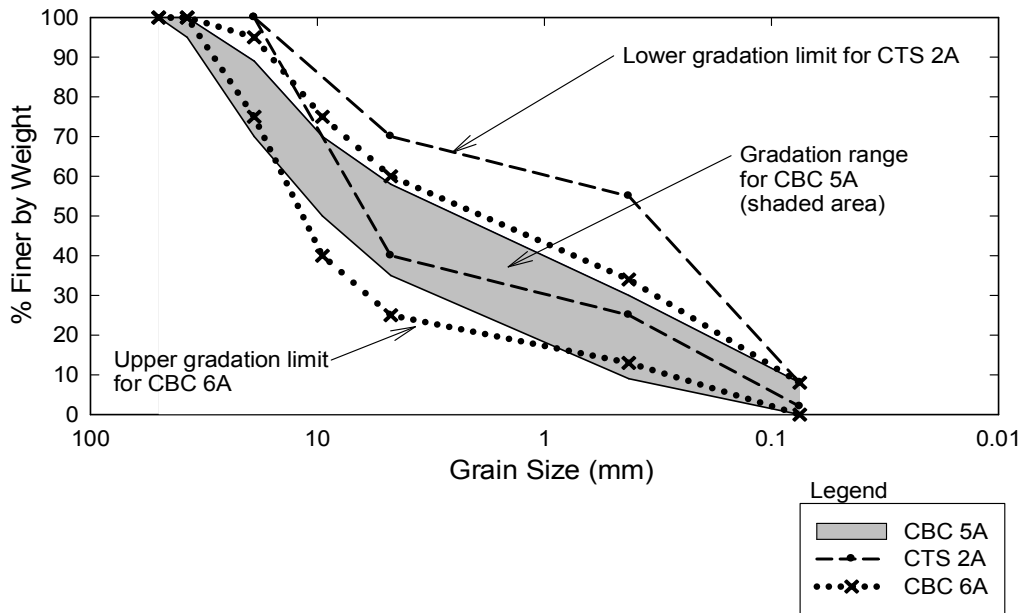


Figure 1. Aggregate grain size distributions based on Montana Supplemental Specifications (Section 701.02.4 ad 701.03.2).

The primary objective of this study will be an experimental evaluation of the most important engineering properties and characteristics of three different types of base course aggregates. Designers would be in a better position to refine and optimize their pavement sections if the performance parameters of the most commonly used aggregates were better quantified. Having a better understanding of the engineering properties of the various aggregates options would alleviate confusion among designers and District personnel regarding differences in customary practices. It would also provide valuable information to construction personnel when faced with requests by contractors to change or modify aggregate types.

3 PROJECT METHODOLOGY

A laboratory experimental study will be conducted to quantify the engineering properties of three different aggregates. The primary properties that will be examined are: strength, permeability, compaction, durability, and stiffness. Based on the test results, comparisons will be made to evaluate the suitability of the three aggregate types for use as base course materials in Montana highway pavement sections. Laboratory tests will be conducted on five samples of each aggregate type, for a total of 15 different materials.

The work plan for this project consists of the following tasks, which are described more fully below. These tasks will provide the data necessary to address the research objectives.

Task 1 – Project Management/Administration

Communicate (or meet) with project technical panel to discuss various aspects of this project. Establish testing procedures and methodologies. Additional communications during the project

will be through quarterly progress reports and a final report at the end of the project. Attend a meeting at MDT Headquarters in Helena near the end of the project to share the final outcome of the research with the technical panel and other interested MDT personnel. Conduct regular internal project meetings and address administrative responsibilities.

Task 2 – Laboratory Tests

Perform laboratory tests on 15 samples of coarse aggregates obtained from multiple representative geographic locations within Montana. The 15 samples will include five samples of each of the three base course aggregates (CBC 5A, CBC 6A, and CTS 2A). Montana Department of Transportation will conduct R-value tests on the same materials and transmit the results to MSU as the tests are completed.

The following laboratory tests will be conducted at the MSU Civil Engineering Department's geotechnical testing facilities. Some of these tests, particularly the permeability and direct shear, will require multiple tests on each of the 15 samples.

- a) Particle size gradation
- b) Specific gravity
- c) Modified Proctor density
- d) Relative density
- e) Los Angeles abrasion/degradation
- f) Permeability*
- g) Direct shear**

*Permeability tests will be conducted on each sample in general conformance with AASHTO D2434. Samples will be compacted into large 10-inch-diameter permeameters and tested using a uniquely designed system that utilizes a Marriotte tube and integral upper reservoir to maintain 100% saturation of the soil sample and testing apparatus throughout the experiment. The proposed test setup can be used to conduct either constant head or falling head tests. It is anticipated that constant head tests will be used. If necessary, the falling head test procedure will be implemented if seepage rates cannot be measured practically using the constant head approach. Because of the sensitivity inherent in permeability testing, at least three tests will be conducted on each material for averaging purposes. Consequently, at least 45 large samples will be prepared and tested as part of this task.

**Strength will be measured using a large (12 in × 12 in) Brainard Kilman direct shear test apparatus. The MSU test machine is retrofitted with a GeoTac data acquisition system, which provides electronic readings of lateral load and horizontal deflection using an S-type strain gauge load cell and an LVDT displacement transducer. Samples will be compacted in 1- to 2-inch-thick lifts using an air driven flat-plate vibrator with a weight of 57 pounds and a 100-square-inch cross section. Samples will be sheared at a constant rate of 0.05 in/min to a maximum horizontal displacement of 3.8 in, or to failure, whichever occurs first. Normal stresses will be developed by applying pressure to the top of the samples with a thick rubber membrane that is inflated with air pressure. An air regulator will be used to control the membrane pressure to provide a constant normal stress throughout the tests. Each material will be tested using at least

three different normal stresses to develop a reasonable representation of the Mohr-Coulomb failure envelope. A minimum of 45 large samples will be prepared and tested as part of this task.

Task 3 – Analyze and Synthesize Results

Assimilate and evaluate results from the laboratory tests. Use statistical methods, as relevant, to compare the measured laboratory results. Summarize and discuss in the final report the relative differences in permeability, strength, and stiffness of the aggregates examined in this study.

Task 4 – Report

Conclude the study with the preparation of a final research report. Results of the proposed study will be clearly and thoroughly documented in conformance with MDT's standard research report format. Using the engineering basis developed in this study, recommendations will be provided regarding the use of the three aggregates examined in this study for construction of highway base course sections. A draft report will be submitted to MDT for review, two months prior to the end of the contract period. Comments received from the reviewers will be incorporated into the final document. A Project Summary Report will be prepared after the report is finalized. Research progress reports will be submitted on a quarterly basis.

4 MDT INVOLVEMENT

The Department's assistance will be beneficial to the proposed research project in the following two areas:

1. Provide samples of aggregates for the proposed laboratory testing program. To meet the objectives of this proposal, the following material samples are needed:
 - (a) 5 samples of CBC 5A
 - (b) 5 samples of CBC 6A
 - (c) 5 sample of CTS 2A

Aggregate samples should be selected to provide a representative variety of materials that could be expected on Montana projects. A relatively large amount of material is required to conduct the proposed testing. We will provide input and recommendations to MDT in regards to aggregate selection and necessary material quantities. MDT, in consultation with MSU, will be responsible for determining the appropriate sources of aggregate to be used in this research. MDT will deliver the soil samples to the MSU Bozeman campus.

2. Conduct R-value tests on samples of the 15 aggregates that will be examined in this study. We suggest that three to five R-value tests should be conducted on each sample.

5 PROJECT STAFFING AND ADMINISTRATION

Dr. Robert Mokwa and Eli Cuelho will be Co-Principal Investigators for this research project. Dr. Mokwa will be the primary manager and the point of contact with MDT. Both P.I.'s will be responsible for ensuring that the objectives of the study are accomplished, implementing the project tasks, and preparing the final report.

5.1 Dr. Robert Mokwa: Principal Investigator

Dr. Robert Mokwa is an Assistant Professor in the Civil Engineering Department at Montana State University. Dr. Mokwa is a licensed professional engineer in the state of Montana with over 18 years of experience covering a broad range of geotechnical, geo-environmental, transportation, and civil engineering research and design projects. His research skills were recognized by his award of the President's College of Engineering Research Excellence Award from his alma mater, Virginia Tech. He currently teaches classes and conducts research in the area of geotechnical engineering, frost heave, soil-structure interactions, deep foundations, and site investigative techniques. He has authored numerous technical publications on these topics. Two relevant studies conducted by Dr. Mokwa for the Montana Department of Transportation include: *Evaluation of the Engineering Characteristics of RAP/Aggregate Blends* and *Soil Air Voids Method for Compaction Control*.

5.2 Mr. Eli Cuelho: Co-Principal Investigator

Mr. Eli Cuelho is a Research Engineer at the Western Transportation Institute at Montana State University. Mr. Cuelho is a licensed professional engineer in the state of Montana and is currently involved with a number of research projects related to the design and maintenance of transportation infrastructure. He has experience with ITS technology evaluation and deployment, cost-effectiveness and cost-benefit analyses, remote sensing and data acquisition equipment, geotechnical engineering, geosynthetic design, and pavement design and analysis. Two relevant studies conducted by Mr. Cuelho for the Montana Department of Transportation include: *Cost Effectiveness of Crack Sealing Materials and Techniques for Asphalt Pavements* and *A Review of the Performance and Costs of Contemporary Pavement Marking Systems*.

5.3 Research Assistants

Dr. Mokwa and Mr. Cuelho will be supported by a graduate research assistant(s) who will work part-time on this project throughout its duration. A proposal will also be submitted to the National Science Foundation REU program to obtain support for an additional undergraduate research student for summer 2006. The research fellow would enhance the scope and breadth of this project, at no additional cost to MDT. The students will conduct laboratory tests, organize and analyze results, and help synthesize the information into the final report.

6 PROJECT SCHEDULE

The estimated project completion schedule is depicted in Table 1. The total proposed duration of the project is 18 months, with an estimated start date of October 1, 2005, and an estimated completion date of March 31, 2007. Projected milestone dates, based on a start date of October 1, 2005, are shown in parenthesis in Table 1.

Table 1. Project Schedule

Months	1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18
Work Tasks										
Project Start	★									
1 – Project Management/Admin.										
2 – Laboratory Tests										
3 – Analyze and Synthesize Results										
4a – Prepare Draft Report										
4b – Address Comments										
4c – Submit Project Summary Report										
4d – Submit Final Report										★

7 PROJECT BUDGET

The funding request to the Montana Department of Transportation for this proposed research project is \$27,392 (itemized costs are provided in Table 2). This amount constitutes 64.2% of the total cost of the project. Matching funds in the amount of \$15,276 (35.8% of the total budget) will be provided by the Western Transportation Institute of Montana State University through the MPART agreement. The total estimated cost of the project is \$42,667.

These budget amounts do not include graduate student tuition, which is often included in research projects involving student work. As an additional contribution to this project, tuition for the graduate student assigned to this study will be paid using UTC funds through WTI. For the 18 month duration of this project, tuition costs for an in-state graduate student are about \$9,050 (2005 rates). *Including tuition covered by WTI, the true match for this project is 47%. Thus, using real dollar amounts, the WTI/MSU team is contributing almost one-half of the total cost of the project.*

In-state travel will cover one trip to MDT for the final presentation for the project. Additional resources (counted as expendable supplies) are needed to cover items such as filter material for the permeameters, maintenance on test equipment, and materials for preparing and storing soils.

Table 3 shows the number of person-hours that will be devoted to each task by research team members. The total number of person-hours needed to complete the work described in this proposal is 1,437. Table 4 shows the dollar amounts associated with each task. Benefits are calculated by multiplying the benefit rate for each individual (Eli Cuelho = 31%, Bob Mokwa = 25%, Student = 4%) by their total salary.

Table 2. Research Budget

Item	MDT	WTI/MSU Match*	Total
Salaries	\$ 17,848	\$ 12,240	\$ 30,088
Benefits	\$ 4,628	\$ 490	\$ 5,118
In-State Travel	\$ 150	\$ 0	\$ 150
Out-of-State Travel	\$ 0	\$ 0	\$ 0
Expendable Supplies	\$ 200	\$ 0	\$ 200
Subcontracts	\$ 0	\$ 0	\$ 0
Direct Costs	\$ 22,827	\$ 12,730	\$ 35,556
Overhead	\$ 4,565	\$ 2,546	\$ 7,111
Total Project Cost	\$ 27,392	\$ 15,276	\$ 42,667

**UTC Fellowship Graduate Student*

Table 3. Summary of Person Hours

Tasks	Bob Mokwa (PI)	Eli Cuelho (co-PI)	Student	Totals
1. Project Management	100	30	0	120
2. Laboratory Testing	50	20	900	970
3. Analysis and Synthesis of Results	50	10	40	110
4. Reporting	125	32	80	230
Totals	325	92	1020	1437

Table 4. Summary of Salary and Benefits for Project Team

Tasks	Bob Mokwa (PI)	Eli Cuelho (co-PI)	Student	Totals
1. Project Management	\$ 4,640	\$ 903	\$ 0	\$ 5,543
2. Laboratory Testing	\$ 2,320	\$ 602	\$ 10,800	\$ 13,722
3. Analysis and Synthesis of Results	\$ 2,320	\$ 301	\$ 480	\$ 3,101
4. Reporting	\$ 5,800	\$ 963	\$ 960	\$ 7,723
Total Salaries	\$ 15,080	\$ 2,768	\$ 12,240	\$ 30,089
Total Benefits	\$ 3,770	\$ 858	\$ 490	\$ 5,118
Totals	\$ 18,850	\$ 3,627	\$ 12,730	\$ 35,207